Pearson Edexcel

Examiners' Report June 2024

IAL Physics WPH13 01

ResultsPlus

Introduction

The IAL paper WPH13 Practical Skills in Physics I assesses the skills associated with practical work in Physics. This document should be read in conjunction with the question paper and the mark scheme which are available at the Pearson Qualifications website, along with Unit 3 and Appendix 10 in the specification.

In this specification, it is expected that candidates will carry out a range of Core Practical experiments. The skills and techniques learned from carrying out these experiments will be examined in this paper, but the Core Practical experiments themselves are not assessed. Candidates who do little practical work will find this paper more difficult as many questions rely on applying the learning to novel as well as other standard experiments.

Candidates are expected to know and use terminology appropriately, and use standard techniques associated with analysing uncertainties at AS Level. These can be found in Unit 3 and Appendix 10 of the specification. In addition, command words may be used to challenge the candidates to form conclusions. These are given in Appendix 9 of the specification, and centres should make sure that candidates understand what the command words mean.

Candidates will be more successful if they routinely carry out and plan practical activities for themselves using a wide variety of techniques. These can be simple experiments that do not require expensive, specialist equipment. In particular, they should make measurements on simple objects using vernier calipers and micrometer screw gauges and complete all the Core Practical experiments given in the specification.

The paper for June 2024 covered the same skills as in previous series and was therefore similar in demand.

Question 1 (a)(i)

This question was set in the context of investigating the force needed to break a rubber band. This type of experiment should be familiar as the techniques are similar to those in Core Practical 5: Young Modulus.

In part (a)(i) candidates had to **identify** two health and safety issues and how they should be dealt with. In general, this was answered well but it was apparent that some candidates confused this experiment with a similar one used in previous series. The majority of candidates correctly identified the risk associated with the rubber band breaking. Some answers were too vague, using phrases such as “hurting the student”, and some referred to “glasses” instead of safety spectacles or goggles. Many candidates thought that the force meter falling would be a safety issue. For this experiment that would not be the case. The most important issue here was the stability of the stand as the diagram shows the base pointing away from the edge of the table. Candidates that did comment on this did well, although some quoted using a mass rather than a heavy mass. In addition, some candidates made impractical suggestions for securing the base, such as using tape or getting another student to hold it.

The following examples scored full marks.

(a) The student suggested pulling down on the force meter until the rubber band breaks.

(i) Identify **two** health and safety issues and how they should be dealt with.

(4)

① the rubber band may snap then hurt eyes. wear goggles or other safety glasses. ② the whole apparatus may topple over if the force too big. fix or clamp the stand and bench. ③ the force meter or apparatus may fall on feet. wear safety shoes.

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Examiner Comments

This candidate referred to three issues, but the final one is irrelevant so can be ignored. Here they refer to the "whole apparatus" falling over, which is acceptable for this context. The idea of "fixing" the stand to the bench is also fine as this implies using an appropriate level of stability.

ResultsPlus
Examiner Tip

If there is a stand in a diagram, check whether it will be stable enough for the investigation.

(a) The student suggested pulling down on the force meter until the rubber band breaks.

(i) Identify **two** health and safety issues and how they should be dealt with.

(4)

The rubber band will snap and may fly into someone's eyes. The student should wear goggles or some such eye protection.
The clamp stand may topple over when the student pulls on the force meter. A counterweight should be placed on the clamp stand.

ResultsPlus
Examiner Comments

This is a very well expressed answer. Here they are using a counterweight to stabilise the stand. This is acceptable as it implies that the mass is heavy enough to stop the stand moving.

ResultsPlus
Examiner Tip

Describe relevant risks and precautions fully in questions regarding health and safety.

Question 1 (a)(ii)

In part (a)(ii) candidates had to **describe** a simple method that would not include the use of a force meter. Most candidates produced a good attempt at this, but as is usual they often missed out on marks because of language being too vague. Most candidates noted that they should use masses, but the idea of adding them gradually was often missed and occasionally they did not state “until the rubber band breaks”. Fewer candidates described how to convert mass to force.

The following examples scored full marks.

(ii) Describe a method the student could use which would **not** include a force meter.

You should include the use of additional apparatus.

(2)

The student can use a ~~spring~~ few slotted masses. Start by adding a mass of 100g ~~and m using a~~ and ~~Newton spring balance~~ check if the band snaps. keep adding masses of 100g to the setup. Instead of using a force meter the student can measure the force required to break the band using F = mg.

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Examiner Comments

This candidate describes the method fully. Although they didn't state keep adding masses until the rubber band breaks, this is implicit in the statement "check if the band snaps". Here, they have also used the word "measure" rather than calculate for the force, but this is acceptable as this was in the stem of the question.

ResultsPlus
Examiner Tip

Describe methods in steps so they can be followed by somebody carrying out the investigation.

(ii) Describe a method the student could use which would not include a force meter.

You should include the use of additional apparatus.

(2)

The student can ~~do this~~ add masses until the rubber band ~~ha~~ is broken. Then use balance to measure the total mass and calculate the force ($F=mg$).

ResultsPlus
Examiner Comments

This candidate has just done enough to score the first mark. The addition of "gradually" or "one at a time" would improve this answer.

ResultsPlus
Examiner Tip

Be clear about how a variable will be varied in an investigation.

Question 1 (b)

In part (b) candidates had to **explain** why it was appropriate to **repeat** the measurements. This question was only answered well by a minority of candidates, although a good number scored a mark. In general, candidates focused on general ideas associated with repeating, such as being able to “spot anomalies” rather than being specific about why there may be variations between the rubber bands, in particular temperature differences. Candidates that scored a mark often used the idea of reducing random error. Note that candidates should not use the idea of avoiding or eliminating for random error. Occasionally, candidates referred to both systematic and random error, which is a contradiction so would not be credited.

The following answers both scored full marks.

(b) The student investigated how the breaking force of the rubber bands changed at low temperature.

The student placed five identical rubber bands in a freezer at −10 °C.

The student removed one rubber band from the freezer and determined the breaking force. He repeated this for the other rubber bands.

Explain why it is appropriate to repeat the measurements.

(2)

The temperature would change when the rubber band is taken from the freezer, and reading force may have parallax, so repeat the measurements and find average value will reduce the random error.

ResultsPlus
Examiner Comments

This candidate has clearly realised that there may be temperature variations once the bands are removed from the freezer.

ResultsPlus
Examiner Tip

Think about what could cause random error in an investigation.

(b) The student investigated how the breaking force of the rubber bands changed at low temperature.

The student placed five identical rubber bands in a freezer at −10 °C.

The student removed one rubber band from the freezer and determined the breaking force. He repeated this for the other rubber bands.

Explain why it is appropriate to repeat the measurements.

(2)

Because each rubber bands may have different temperature, little higher or lower than −10°C. Measuring for many times and take average could reduce the random error.

ResultsPlus
Examiner Comments

Although this candidate has not stated that removing from the freezer may cause temperature variations, they have done just enough to identify what the random error would be for this investigation.

ResultsPlus
Examiner Tip

Remember that repeating a measurement is a technique to reduce random error.

Question 2 (a)(i)-(ii)

This question was set in the context of investigating a ball bouncing from an angled slope. Although this is not related to a Core Practical, it is a simple experiment that can be used to practise planning and using experimental techniques.

In part (a) candidates had to **identify** and **explain** a control variable for this investigation. This was not answered well. Many candidates focused on the apparatus, such as the ball or the surface of the slope, rather than how the ball was placed for each measurement. In general, it is expected that the apparatus stays the same during an experiment as the question refers to the apparatus as shown, so these are not considered as control variables. Some candidates referred to the angle of the slope, which was the variable being investigated. Some candidates did refer to the initial position of the ball, but as this was given in the question it could not be credited unless the height was referred to. Explaining why the height needed to be controlled produced general answers regarding control variables rather than using physics knowledge to explain why controlling the height was necessary. This was expressed in a variety of ways, but candidates had to be careful with their wording as some referred to the acceleration changing, or just referred to energy instead of gravitational potential or kinetic energy. Occasionally, candidates referred to an incorrect velocity.

The following example scored full marks.

(a) (i) State **one** control variable for this investigation.

(1)

~~the~~ The height where ball was released. and the height where ball hit the slope.

(ii) Explain why it is necessary to control this variable.

(2)

~~er~~ Energy is conserved. so $mgh = \frac{1}{2}mv^2$

$\Rightarrow$ $v = \sqrt{2gh}$, if h is a constant. the velocity is a constant.

ResultsPlus
Examiner Comments

This candidate has correctly identified the control variable. The explanation here does not explicitly include gravitational potential energy, but by deriving the velocity and stating that *h* is constant it is good enough for the first mark. Here, they have talked about velocity, which is assumed to be the velocity at the slope unless they have stated otherwise.

ResultsPlus
Examiner Tip

Think about what could vary using the apparatus as is shown in the diagram when looking for a control variable.

Question 2 (b)

In part (b) candidates had to **criticise** the recording of the data. This is a familiar type of question from previous series so candidates did this well. Most candidates realised that the readings for both variables had inconsistent decimal places. Similarly, candidates also realised that there was not enough data to draw a reliable graph, although occasionally the wording appeared to merge this with repeating to determine a mean. A few candidates stated that a value did not fit the pattern, but they did not state specifically which point they were referring to.

Criticise the recording of the data.

(3)

* There are only 3 Sets of data in the table.

* The decimal points of both θ and x values are inconsistent.

* There are no repeat readings in the table.

ResultsPlus Examiner Comments

This candidate scored the three most common marks. Here they have referred to "only" three sets of data, which is just enough to imply there are not enough sets of readings to draw a graph. This candidate refers to the decimal "points" for both values being inconsistent. It is good practice to refer to decimal places for measurements.

ResultsPlus Examiner Tip

Be clear about how many sets of data are needed to draw a reliable graph.

Criticise the recording of the data.

θ has ~~inson~~ inconsistent significant figures

X also has inconsistent significant figures

No repeat readings

not enough measurements (minimum 5) for θ

ResultsPlus
Examiner Comments

This candidate has referred to the significant figures for each variable separately. In this case this was acceptable but it is good practice to refer to decimal places for measurements. This candidate has clearly stated how many sets of readings are needed for a reliable graph.

ResultsPlus
Examiner Tip

Measurements should be recorded to a consistent number of decimal places, usually the resolution of the instrument.

Question 2 (c)

In Part (c) candidates had to **explain one** modification that would reduce the error stated, ie that the ball was moving too quickly. Candidates performed better than expected on this question, and some produced novel but impractical ideas. Using a camera to record the motion of the ball was the most popular, but some descriptions were not detailed enough to gain marks. Some candidates used sand trays or other powders at the landing sites, which were worthy of credit. The second mark was for the explanation, therefore the candidates had to explain how their method would reduce the error. Some candidates described using paint or another liquid to cover the ball. This was only given some credit as this would be impractical.

The following examples both scored full marks.

You should include additional apparatus.

(2)

Using video camera to record the experiment. ~~The~~ Check the video frame by frame to find which point the ball landed. Repeat and calculate the mean.

ResultsPlus
Examiner Comments

This candidate has used a video camera, which is enough to imply recording the motion of the ball rather than taking still images. Watching the video "frame by frame" is another way of describing slow motion.

ResultsPlus
Examiner Tip

Think about the significant source of error in an investigation when suggesting a modification.

(c) The student wrote a laboratory report about her investigation.

She reported that the most significant source of error was being unable to judge the exact point where the ball landed. This was because the ball moved too quickly.

Explain **one** modification she could make to the apparatus to reduce this error.

You should include additional apparatus.

(2)

The student could set up the experiment over sand so that when the ball falls it leaves a mark. Or she could record the ball falling and place a ruler to see the distance.

ResultsPlus
Examiner Comments

This is an example that uses sand. It is described just well enough to score the marks, although a sand pit or sand box would improve this answer.

ResultsPlus
Examiner Tip

Modifications should be practical, like this one is, as this is easily repeatable.

Question 3 (a)

This question was based on using a pulse-echo technique to determine the speed of ultrasound. Although this was an unfamiliar context, the use of an oscilloscope to measure time is found in Core Practical 6: Speed of Sound.

In part (a) candidates had to **describe** an **accurate** method to determine a **single value** of the distance *s* using a metre rule. This was answered well. The first mark was for describing how to place the metre rule, which most candidates described well. The final mark for a technique in using the metre rule was awarded most often. In both cases, some candidates did not use terminology correctly. For example, “straight” is not a suitable alternative for “vertical”. Both perpendicular and parallel need to be relative to something, eg perpendicular to the floor. In addition, it appeared that the two terms were confused with each other. Similarly "align" needs further description. It is also recommended that candidates avoid the use of “horizontal” when describing taking measurements from the ruler as the use depends on the context.

The second mark was for obtaining a value for *s* which many candidates did not do or did not describe adequately. Candidates that described this sometimes forgot to subtract the two values or placed the “end” of the ruler somewhere rather than aligning the zero with a specific place. Some candidates simply wrote “check for zero error” which was not enough. As this was a **single** value, repeating and calculating the mean was not accepted.

The following examples both scored full marks.

Your method may include additional apparatus.

(3)

~~A~~A metre rule can be clamped onto a stand next to the tube ~~stand~~ with a weight at its bax to ensure it doesn't fall. A set square can be used to ~~et~~ ensure the metre rule is parallel ~~to~~ to the tube. The zero mark should align with the bottom of the ultrasonic Transducer to prevent zero error. when taking readings the students eye level should be at the bottom of s to prevent parallax error

ResultsPlus
Examiner Comments

This is a very full answer. The candidate has stated "next to the tube" which can be too vague, so it is better to say "close to". Here they have used "parallel to the tube" which is acceptable for vertical in this case. They have stated where the zero mark should be. The description of how and where to read off the ruler is just enough to be awarded the mark, but reading perpendicular to the scale is a better way of describing this.

ResultsPlus
Examiner Tip

Think about how to place a metre rule so that it is vertical and does not move.

Your method may include additional apparatus.

(3)

make sure the meter rule is perpendicular to the horizontal using a set square.
Use a meter rule with 0cm at the bottom of ultrasonic transducer.
Put it close to the tube as close as possible.
Read length where the scale is at the level of water surface.
Read with eye level perpendicular to scale by using a set square.
Repeat measurement and take average.

ResultsPlus Examiner Comments

This candidate has described the method very well. Only clamping the metre rule in place would improve this method.

ResultsPlus Examiner Tip

Describe a method in steps so that it could be followed by someone setting up the apparatus and taking the measurement.

Question 3 (b)

In part (b) candidates had to **show that** the speed of ultrasound in air was about 330 m s^{-1}. This performed better than expected. The first mark was for calculating the time between the pulses displayed on the oscilloscope screen. As this was a “show that” question, the calculation was expected but was often missing. Some candidates appeared to use the vertical distance or the width of the pulses. Some candidates marked this on the diagram which was helpful. The majority of candidates used the formula for velocity, although a small number appeared to forget to halve the time or double the distance in their calculation, but then went on to double the velocity which was not accepted. Some candidates also used the formula for wave speed which, although dimensionally is correct, is incorrect physics. Candidates should also note that all working must be shown to be awarded marks in a “show that” question, and answers should be given to one more significant figure than the answer.

The following example scored full marks.

Total time = $0.5 \times 10^{-3} \times 6$ s

$t = \frac{0.5 \times 10^{-3} \times 6}{2} = 1.5 \times 10^{-3}$ s

s = 0.487 m

$v = \frac{s}{t} = \frac{0.487}{1.5 \times 10^{-3}} = 331.3$ ms^{-1} (≈ 330)

ResultsPlus
Examiner Comments

This candidate shows a clear calculation of the time between the pulses on the first line, then halves this time. There is a clear substitution into *v* = *s* / *t* to arrive at the final answer. This calculation is clear and easy to follow.

ResultsPlus
Examiner Tip

When determining time from an oscilloscope screen, show the calculation clearly.

Question 3 (c)(i)-(ii)

Part (c) involved **calculating** a mean and percentage uncertainty from a set of data. Most candidates scored marks. It is not expected that candidates identify and remove an “anomalous” data point from these calculations, but those that did were given some credit. In part (c)(i) the first mark was for a calculation of the mean, which most candidates managed. The final mark was for the correct value of the mean given to the **same number of significant figures as the data** . Many candidates gave too many significant figures or did not give the unit.

In part (c)(ii) the candidates **must show** the calculation for the first mark, and this is awarded for calculating the **half range or furthest from the mean**. The final mark was for the correct percentage uncertainty. Candidates should note that percentage uncertainties should be given to one or two significant figures.

The following examples show common errors in part (c)(i) but full marks in part (c)(ii).

(i) Determine the mean value of v. **(2)**

mean value = $\frac{335+347+339+342}{4}$ = ~~340.75~~ 341 m

Mean value of v = 341m

(ii) Determine the percentage uncertainty in the mean value of v. **(2)**

%u = $\frac{\text{half range}}{\text{mean value}} \times 100\%$ = $\frac{\frac{1}{2}(347-335)}{341} \times 100\%$ = 1.76%

Percentage uncertainty = 1.76%

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Examiner Comments

Although this one has a unit in part (c)(i), it is incorrect. However, the form of the answer matches the data. The calculation in part (c)(ii) is very clear with a correct answer.

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Examiner Tip

Include units on mean values. Use the same number of decimal places for measurements, or significant figures for derived quantities, when calculating the mean of a set of data.

(i) Determine the mean value of *v*.

(2)

mean = (335 m/s + 347 m/s + 339 m/s + 342 m/s) ÷ 4

= 340.75 m/s

Mean value of *v* = 340.75 m/s

(ii) Determine the percentage uncertainty in the mean value of *v*.

(2)

percentage uncertainty = $\left(\frac{max - min}{2}\right)$ ÷ mean = $\left(\frac{347 - 335}{2}\right)$ ÷ 340.75 × 100%

= 1.76%

Percentage uncertainty = 1.76%

ResultsPlus
Examiner Comments

The unit is correct, but there are too many significant figures on the answer. Another clear calculation in part (c)(ii).

ResultsPlus
Examiner Tip

Quote percentage uncertainties to one or two significant figures.

Question 3 (d)

In part (d) candidates were given a calculated value for the speed of sound in water with its percentage uncertainty. They were asked to **deduce whether** the value was consistent to an accepted value of the speed of sound in water. This was generally done well as this is now a familiar type of question, although the most common error was calculating the limits of the stated velocity rather than the calculated velocity. The final mark was for a correct conclusion including a comparison between relevant values. Candidates appear to be using “compare and conclude” more routinely, but sometimes the comparison or statement was missing.

The following examples scored full marks with different ways of stating a conclusion.

Your answer should include a calculation.

$1444 \times (1 + 4\%) = 1501.76\ \text{ms}^{-1}$.

$1444 \times (1 - 4\%) = 1386.24\ \text{ms}^{-1}$

So $1386.24 <$ acceptable value < 1501.76

So $1481\ \text{ms}^{-1}$ is acceptable.

ResultsPlus
Examiner Comments

This candidate has calculated a range, which is acceptable. There was no need to calculate the lower limit as the value of the calculated speed of sound was below the accepted value. The comparison is mathematical, but it is clear with a valid statement which answers the question.

ResultsPlus
Examiner Tip

Ensure the comparison is explicit, either in words or as a mathematical expression.

(2)

$\frac{4}{100} \times 1444 = 57.76$ $57.76 + 1444 = 1502$ m/s. The student's value is consistent with the accepted value because ~~it~~ the accepted value lies within the upper limit of the student's value, with the upper limit being 1502 m/s.

ResultsPlus
Examiner Comments

This candidate has only calculated the upper limit, which is acceptable as the calculated speed of sound is less than the accepted value. The comparison here is in words, with a statement that answers the question.

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Examiner Tip

Ensure that the conclusion contains a comparison and a statement that answers the question.

Question 4 (a)(i)

This question included plotting and analysing the graph for an investigation involving the resistance of a loop of metal wire. This context is similar to Core Practical 2: Electrical Resistivity. A question involving a graph appears in each series and the mark scheme follows a common format. Therefore, there are plenty of opportunities to practise this skill and consult Examiners' Reports to correct common errors.

Part (a) involved determining the diameter of the wire using a micrometer screw gauge. Using a micrometer screw gauge can be found in several Core Practicals. In part (a)(i) candidates had to **determine** the percentage uncertainty in a single measurement of the diameter of the wire. It is expected that the uncertainty in a **single** measurement is **half** the resolution. Some candidates used the full resolution, which was not accepted. Some candidates used resolutions of 0.1 mm or 0.001 mm despite the diameter being given to two decimal places. Candidates should note that percentage uncertainties should be given to one or two significant figures.

The following example scored full marks.

4 A student made measurements on a length of metal wire.

(a) The student used a micrometer screw gauge to measure the diameter d of the wire.

(i) The student recorded a single measurement of d as 0.27 mm.

Determine the percentage uncertainty in this measurement.

(2)

~~resolution =~~

~~Uncertainty = ± 0.005 mm~~ resolution = 0.01 mm

uncertainty = $\frac{0.01}{2}$ = ±0.005 mm

percentage uncertainty = $\frac{0.005}{0.27} \times 100$ = 1.85%

Percentage uncertainty = 1.85%

ResultsPlus
Examiner Comments

This is an excellent example showing a full calculation. It is good practice to state the resolution of the instrument as this may count as a mark in similar questions. The calculation is shown clearly with a correct answer. This candidate has chosen to show this in steps, but a single calculation would also be acceptable.

ResultsPlus
Examiner Tip

Start recording percentage uncertainties to one or two significant figures.

Question 4 (a)(ii)

In part (a)(ii) candidates had to **explain** another **technique** when using the micrometer screw gauge. This was more challenging than expected as many candidates described another **method**, such as folding the wire over and measuring multiple diameters. The second mark was rarely achieved. An explanation should refer to the type of error, in this case systematic error.

The following answer scored full marks.

(ii) The student repeated the measurement of *d* at different positions and orientations and calculated the mean.

Explain another technique she should use to determine an accurate value for *d*.

(2)

· check and correct for zero error of the micrometer

· reduce systematic error

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Examiner Comments

This candidate has stated the relevant technique for calibrating the instrument. Note that this candidate has given more than was required at AS Level, but this is good practice for A2 Level. This techniques was then explained in terms of errors. It is acceptable to use "reduce" for systematic errors, but not "eliminate" for random errors.

ResultsPlus
Examiner Tip

Understand the difference between a technique used to reduce errors, either systematic or random, and a method.

Question 4 (b)

In part (b) candidates had to **explain** why a fixed resistor was used in the circuit. Most candidates scored some marks, but these were for general comments regarding limiting the current. Some candidates referred to "controlling" the current, which was too vague and could only be credited if it was related to the maximum current. The second mark was for the explanation, and this was often just a general statement rather than specifically explaining why the current should be limited.

The following examples both scored full marks using different explanations.

Explain why the fixed resistor is included in the circuit.

(2)

to limit the maximum current in the circuit so that the wire does not become too hot

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Examiner Comments

This candidate related limiting current to a safety issue regarding the wire becoming too hot.

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Examiner Tip

Understand the function of resistors in a circuit.

Explain why the fixed resistor is included in the circuit.

(2)

- to limit the current in circuit
- without fixed resistor, if XY=0, the power of cell is too large and may be damaged.
- to ~~preot~~ protect ammeter and voltmeter.

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Examiner Comments

This candidate appears to be thinking about the possibility of a short circuit occurring.

Question 4 (c)(i)

In part (c) candidates were given the relationship between resistance and length for the loop of metal wire. In part (c)(i) they were asked to **explain** how a graph of *R / L* against *L* could be used to determine the value of the resistivity *r*. This was more difficult than similar questions in previous series as this related to the *y*-intercept instead of the usual gradient. As the formula needed no manipulation, the first mark was for relating the formula to *y* = *mx* + *c* **and** stating that the *y*-intercept was equal to *r / A*. Some candidates wrote the comparison beneath the formula, which was given credit, but some missed out the + and = which is not credited. Some candidates stated that *c* = *r / A*. without stating what *c* represents. As this is an "explain" question, candidates are expected to explicitly state what *c* (or *m*) refers to. The final mark was for describing how to calculate *r* using the *y*-intercept, although some candidates did not manipulate this correctly.

The following examples both scored full marks.

(i) Explain how a graph of $\frac{R}{L}$ against L can be used to determine the value of ρ. **(2)**

$\frac{R}{L} = -kL + \frac{\rho}{A}$

in the form $y = mx + c$

$\frac{\rho}{A}$ is the y-intercept, so $\rho = A \times$ y-intercept

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Examiner Comments

This is an excellent example where the candidate has written *y* = *mx* + *c* below the formula to check that the formula is in the same order. This is good practice as formulae often require manipulation. The arrows on their own would not be enough to score marks, but the candidate has stated what the *y*-intercept is and a formula to calculate *ρ.*

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Examiner Tip

Check that the formula is in the same order as *y* = *mx* + *c.*

(i) Explain how a graph of $\frac{R}{L}$ against L can be used to determine the value of ρ.

(2)

$\frac{R}{L} = -kL + \frac{\rho}{A}$ just like $y = mx + c$. $\frac{\rho}{A}$ is c and is y-intercept. and A is the cross-sectional area of the wire. that will not change. y-intercept time A, then can get the value of ρ

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Examiner Comments

This candidate has written *y* = *mx* + *c* after the formula, which is fine as it was given in the correct order in the question. There is a clear statement about what the *y*-intercept represents. This candidate has used words to describe how to calculate *ρ*.

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Examiner Tip

State explicitly what *m* and *c* represent by using the words gradient and *y*-intercept. Make it clear how to use these to determine the constant in the question.

Question 4 (c)(ii)-(v)

Part (c)(ii) assessed the candidates' ability to process the data. To gain these marks, the values must be **correct** and given to a **consistent** number of significant figures.

A small number of candidates did not know how to calculate *R / L* . The most common errors were calculating *V* ÷ *I* or *V* ÷ *I* × *L*. Other variations were seen and provided the data had been processed in some way, candidates were given credit for the graph and subsequent parts.

Part (c)(iii) involved plotting the graph of *R / L* against *L*. This scored better than in previous series as graph plotting appears to have improved. The first mark was for placing the axes the correct way around and labelling with the correct quantity. The most common mistake is not using the correct format for labelling the axes, either by missing out the brackets or units or both. The correct form is quantity / unit, eg *L* / m. The most common error was using the format quantity (unit), eg *L* (m) despite the correct format being given in the table for *L*, or not including a unit for *R / L*.

The second mark was for choosing an appropriate scale. At this level, the candidates should be able to choose the most suitable scale so that the small squares are in **values of 1, 2, 5 and their multiples of 10** such that **all** the plotted points occupy **over half the grid in both directions**. Candidates should realise that although the graph paper given in the question paper is a standard size the graph does not have to fill the grid. In most cases a landscape graph unnecessary. Candidates at this level should also realise that scales do not have to start from zero, and this was the most common error. Scales based on 3, 4 (including 0.25) or 7 are awkward and not accepted. Candidates should label every major axis line, ie every 10 small squares, with appropriate numbers so that examiners can easily see the scale used. Occasionally, candidates shifted their values, such as 10.3, 11.3 etc, which sometimes lead to plotting errors.

Two marks are awarded for accurate plotting. Candidates should use **neat crosses** (x or +) rather than dots when plotting points. Candidates were not awarded marks if they used large dots that extended over a small square or used an awkward scale. Mis-plots were uncommon but candidates should check a plot if it lies far from the best fit line.

The final mark is for a **reasonable** best-fit line, and this mark was awarded often. A reasonable best-fit line should have plots either side of the line and cannot be rotated. Other reasons for not awarding this mark are the line being too thick, ie over half a small square, being discontinuous, or having a clear bend. Candidates should use a one piece, 30 cm ruler for this examination.

This is an example of a graph that scored full marks.

(ii) The student recorded the following data.

$V = IR$.
$R = \frac{V}{I}$.

L / m	I / A	V / V	$\frac{R}{L}$ / Ω m^{-1}
0.100	0.720	1.40	19.4
0.200	0.390	1.39	17.8
0.300	0.290	1.42	16.3
0.400	0.250	1.48	14.8
0.500	0.220	1.47	13.4
0.600	0.210	1.47	11.7

Complete the table with the corresponding values of $\frac{R}{L}$

(2)

(iii) Plot a graph of $\frac{R}{L}$ on the y-axis against L on the x-axis on the grid opposite.

(5)

(iv) Determine the value of k from the graph.

(3)

$(0.060, 20.0)$ $(0.580, 12.0)$
x_1 y_1 x_2 y_2

Gradient $= m = \frac{y_2 - y_1}{x_2 - x_1}$

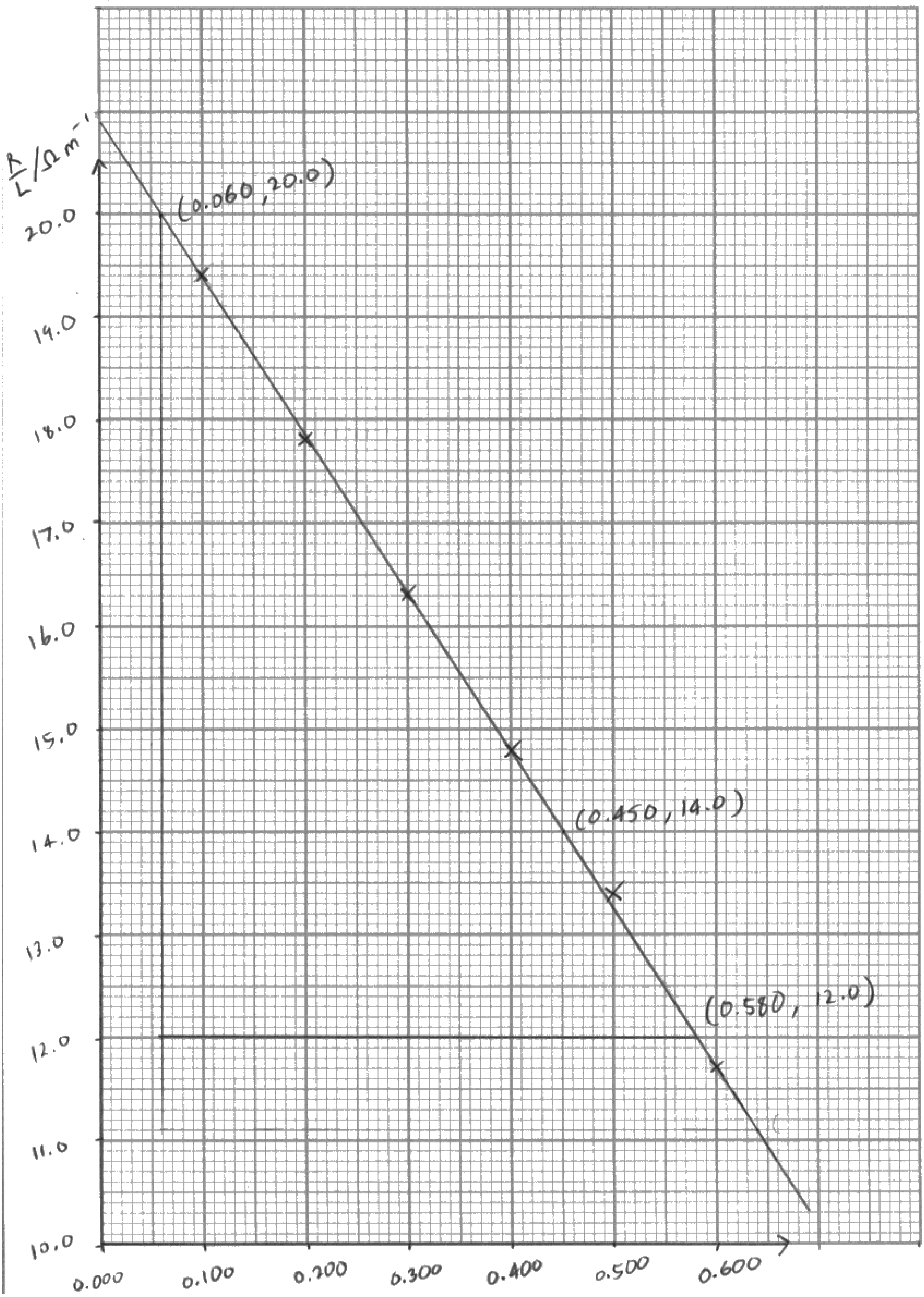
$= \frac{12.0 - 20.0 \ \Omega \ m^{-1}}{0.580 - 0.060 \ m}$

$= -15.384... \ \Omega m^{-2}$

$\approx -15.4 \ \Omega m^{-2}$

$k =$ 15.4 Ω m^{-2}

$m = -k$
$k = -m$
$= -(-15.4)$
$= 15.4 \ \Omega m^{-2}$


R/L / Ω m⁻¹
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
0.000
0.100
0.200
0.300
0.400
0.500
0.600
(0.060, 20.0)
(0.450, 14.0)
(0.580, 12.0)

(v) Determine the value of ρ from the graph.

$d = 0.27$ mm

Point on line of best fit → (0.450, 14.0) **(3)**

$y = mx + c$

$c = y - mx$

$= 14.0 - (-15.4) \times 0.450$

$c = 20.93$

$c = \frac{\rho}{A} \Rightarrow \rho = cA$

$\rho = c\left(\frac{\pi d^2}{4}\right)$

$= 20.93 \times \left(\frac{\pi \times (0.27 \times 10^{-3})^2}{4}\right)$ $\rho =$ 1.2×10^{-6} Ω m

$\approx 1.2 \times 10^{-6}$ Ω m (2sf)

(Total for Question 4 = 21 marks)

ResultsPlus
Examiner Comments

This graph has axes labelled correctly, a sensible scale with accurate plotting and a reasonable best-fit line. This candidate also extended the line to the *y* axis, which is good practice. Note that the candidate has drawn a large triangle using sensible points that covers over half the line. They have also labelled the points which reduces the probability of errors in data extraction.

ResultsPlus
Examiner Tip

Learn what is expected when drawing graphs, and practise drawing them using different data.

In part (c)(iv) candidates were asked to determine the value of *k* from the graph. There were several common errors seen. The first mark is for using a **large triangle that covers at least half the best-fit line** to calculate the gradient of the graph. Many candidates used the first and last points, or other data points from the table. This is only acceptable if the data points lie **exactly** on the best fit line. Candidates should find places where the best-fit line crosses an intersection of the grid lines near the top and bottom of the best-fit line and **mark these as a triangle on the graph**. Candidates that used awkward scales were often only successful when sensible values were used. The final mark could be awarded from an incorrect calculation, but often candidates used too many or too few significant figures, included the – sign or omitted units.

The following example scored full marks.

(ii) The student recorded the following data.

V = IR.

R = V/I.

L / m	I / A	V / V	$\frac{R}{L}$ / Ω m^{-1}
0.100	0.720	1.40	19.4
0.200	0.390	1.39	17.8
0.300	0.290	1.42	16.3
0.400	0.250	1.48	14.8
0.500	0.220	1.47	13.4
0.600	0.210	1.47	11.7

Complete the table with the corresponding values of $\frac{R}{L}$

(2)

(iii) Plot a graph of $\frac{R}{L}$ on the y-axis against L on the x-axis on the grid opposite.

(5)

(iv) Determine the value of k from the graph.

(3)

(0.060, 20.0) (x_1, y_1) (0.580, 12.0) (x_2, y_2)

Gradient = m = $\frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{12.0 - 20.0 \ \Omega \ m^{-1}}{0.580 - 0.060 \ m}$

$= -15.384... \ \Omega m^{-2}$

$\approx -15.4 \ \Omega m^{-2}$

$k =$ 15.4 Ω m^{-2}

m = −k

k = −m

= −(−15.4)

= 15.4 Ω m^{-2}

(v) Determine the value of ρ from the graph.

$d = 0.27\,\text{mm}$

Point on line of best fit $\rightarrow (0.450, 14.0)$

(3)

$y = mx + c$.

$c = y - mx$.

$= 14.0 - (-15.4) \times 0.450$

$c = 20.93$.

$c = \frac{\rho}{A} \Rightarrow \rho = cA$.

$\rho = c\left(\frac{\pi d^2}{4}\right)$

$= 20.93 \times \left(\frac{\pi \times (0.27 \times 10^{-3})^2}{4}\right)$

$\approx 1.2 \times 10^{-6}\ \Omega\,\text{m}$ (2sf)

$\rho =$ $1.2 \times 10^{-6}\ \Omega\,\text{m}$

(Total for Question 4 = 21 marks)

ResultsPlus
Examiner Comments

This calculation follows on from the graph shown above. The candidate has also included the units in the calculation, which can help to determine the units for the constant.

ResultsPlus
Examiner Tip

Draw a large, labelled triangle on the graph. Use sensible points and ensure the triangle covers at least half of the best-fit line.

In part (c)(v) candidates were asked to determine the value of *r* from the graph. Those candidates that used the *y* intercept were the most successful, although those that did not start their *x* axis from zero mistakenly used this value. Some candidates used their calculated gradient and a data point from the best-fit line. Some common errors were substituting a positive value for *k* when *k* was given as negative, or using a point from the table that did not lie on the best-fit line. A number of candidates did not know how to calculate the cross sectional area of the wire or made power of ten errors. The final mark was for the correct answer given to two or three significant figures with a unit. In general, candidates did use a suitable number of significant figures, but there were unit errors including missing units or using m^{-1}.

The following examples both scored full marks but using different methods.

(v) Determine the value of ρ from the graph.

$d = 0.27\,\text{mm}$

Point on line of best fit $\rightarrow$ (0.450, 14.0)

(3)

$y = mx + c$.

$c = y - mx$.

$= 14.0 - (-15.4) \times 0.450$

$c = 20.43$.

$c = \frac{\rho}{A} \Rightarrow \rho = cA$.

$\rho = c\left(\frac{\pi d^2}{4}\right)$

$= 20.93 \times \left(\frac{\pi \times (0.27 \times 10^{-3})^2}{4}\right)$

$\approx 1.2 \times 10^{-6}\,\Omega\,\text{m}$ (2sf)

$\rho =$ $1.2 \times 10^{-6}\,\Omega\,\text{m}$

(Total for Question 4 = 21 marks)

ResultsPlus
Examiner Comments

This example follows on from the graph above. Even though the candidate had extrapolated back to the *y* axis, it was not used in the calculation. Instead the candidate used another data point from the best-fit line and their stated value for *k.* This candidate used the signs correctly. Although there is no stated value for the area, the calculation is clear, leading to the correct answer stated to two significant figures with the correct unit.

ResultsPlus
Examiner Tip

If a gradient or constant from a previous part is being used, ensure it is substituted as stated in the previous part. Data points being used must lie on the best-fit line.

(v) Determine the value of ρ from the graph.

$d = 0.27\,\text{mm}$

(3)

y-intercept $= 21.0\ \Omega\,m^{-1}$

$r = 1.35 \times 10^{-4}$

$A = \pi \times (1.35 \times 10^{-4})^2 = 5.73 \times 10^{-8}\ m^2$

$21.0 \times 5.73 \times 10^{-8} = 1.20 \times 10^{-6}\ \Omega m$

$\rho = 1.20 \times 10^{-6}\ \Omega m$

ResultsPlus
Examiner Comments

This candidate had extrapolated the best-fit line to the *y* axis and read it correctly from the graph. Including the units on this value was not necessary but would have helped determine the unit on the final answer. This candidate chose to calculate the area separately. There is a clear calculation leading to the correct answer, this time given to three significant figures with the unit.

ResultsPlus
Examiner Tip

State the values from the graph that will be used in the calculation. Including units in intermediate calculations will help avoid errors in units for final answers.

Paper Summary

Based on their performance on this paper, candidates should:

- Learn what is expected from different command words, in particular the difference between describe and explain.
- Be able to describe how to measure lengths, angles, force, time, potential difference and current using appropriate apparatus and techniques.
- Refer to random or systematic errors when explaining techniques.
- Practise writing experimental methods including identifying safety issues specific to that experiment.
- Show working in all calculations and include units.
- Choose graph scales that are sensible, ie the value of the smallest square is 1, 2 or 5 and their powers of ten only, so that at least half the page is used. It is not necessary to use the entire grid if this results in an awkward scale, eg 0.25, 3, 4 or 7.
- Plot data using neat crosses (x or +) and check any points that lie far from the best-fit line.
- Use a one piece, 30 cm ruler to draw straight best-fit lines. Ensure there are data points on both sides of the line and that the line cannot be rotated.
- Draw a large triangle that covers at least half of the best-fit line using sensible points. Labelling the triangle often avoids mistakes in data extraction.
- Learn the definitions of the terms used in practical work and standard techniques for analysing uncertainties at AS Level. These are given in Unit 3 and Appendix 10 of the IAL specification.